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Disposition of Excess Weapons Plutonium from Dismantled Weapons

Leslie J. Jardine

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DISPOSITION OF EXCESS WEAPONS PLUTONIUM FROM DISMANTLED WEAPONS

Topics for Potential Collaborative Research Among U.S. and Russian Scientists

LESLIE J. JARDINE
Lawrence Livermore National Laboratory
P.O. Box 808, Livermore, CA 94550, USA

1. Introduction

With the ending of the Cold War and the implementation of various nuclear arms reduction agreements, the United States and Russia have been actively dismantling tens of thousands of nuclear weapons. As a result, large quantities of fissile materials, including more than 100 tons of weapons-grade plutonium, have become excess to both countries' military needs. To meet nonproliferation goals and to ensure the irreversibility of nuclear arms reductions, this excess weapons plutonium must be placed in secure storage and then, in a timely manner, either used in nuclear reactors as fuel or discarded in geologic repositories as solid waste.

Disposition of excess weapons plutonium in the United States and Russia must be accomplished in a safe, secure manner and as quickly as practical. Storage of this plutonium is a prerequisite to any disposition process, but the length of storage time is unknown. Whether by use as fuel or discard as solid waste, disposition of that amount of plutonium will require decades; thus secure storage for plutonium also will be needed for decades—and perhaps longer, if disposition operations encounter delays. Neither the United States nor Russia believes that long-term secure storage is a substitute for timely disposition of excess plutonium, but long-term, safe, secure storage is a critical element of all excess plutonium disposition activities.

2. Proposed Topics for Potential Collaborative NATO Proposals

Given this scenario, the author proposes for workshop discussion following this plenary session, and for collaborative endeavor among scientists of NATO countries and of Russia and other countries in the former Soviet Union, the following topics involving excess weapons plutonium.

2.1 USE OF EXISTING UNDERGROUND GEOLOGIC STRUCTURES FOR INTERIM (10–100 YEARS) STORAGE OF EXCESS PLUTONIUM

Russia's approach to dispositioning excess weapons plutonium is to use it as mixed-oxide (MOX) fuel in nuclear reactors and then to reprocess the spent MOX fuel, recycling the recovered plutonium for further use as MOX fuel. However, facilities for the first steps of this approach—converting the excess weapons plutonium components to plutonium oxide and fabricating MOX—are not available on a large scale in Russia. Although using existing light-water reactors would result in shorter disposition time than would constructing, licensing and starting up new water or fast reactors (which would require an additional five to ten years), Russia has a very limited number of reactors capable of using MOX once it can be produced.

Thus, while Russia builds facilities for plutonium oxide production and MOX fabrication and modifies existing reactors to use the MOX, the excess plutonium must be stored securely to ensure nonproliferation. Depending on schedules for implementing these facilities, the available economic resources and, thus, ultimate installed annual capacities for dispositioning of excess plutonium, disposition of 50 tons of excess plutonium in Russia could require more than 30, perhaps even 50, years. Thus, storing (for periods potentially as long as 50 years) excess-weapons plutonium prior to conversion to oxide is a certain event that requires planning and action today.

Russia is presently constructing a major storage vault at Mayak for weapons components. It will have 50,000 storage positions, only half the number, according to [1], needed to handle the anticipated amount of excess fissile material from dismantled weapons. An alternative to finding a second site to construct a second storage facility or to expanding the Mayak facility, should that even be physically and technically viable, is to identify existing excavated underground structures in Russia that could be converted, modified, upgraded and used for interim storage of excess weapons plutonium, pending its disposition in reactors as MOX.

Excavated underground structures in geologic formations (such as those in the arctic that were used for the nuclear navy fleet or at those at Krasnoyarsk-26 that were used for plutonium production) exist within Russia and could be assessed for possible conversion to provide safe and secure storage of excess plutonium. At the Nevada Test Site, the United States recently conducted an assessment of tunnels previously excavated into a large hill for this purpose [2]. The author strongly recommends identifying such underground structures in Russia and assessing the feasibility of rapidly and effectively converting them into secure plutonium-storage facilities. Such an assessment would show whether the time and cost of upgrading or modifying these existing underground structures are less than those of trying to add capacity to the single facility under construction at Mayak or to siting and constructing a second facility elsewhere.

It is proposed that the United States and Russia collaborate on planning an assessment to establish the feasibility and benefits (e.g., reduced time and cost) of developing a specific location into an underground, excess-plutonium storage facility comparable to the facility being constructed at Mayak. The elements of this assessment could include the following:

- Develop and document a set of storage requirements to guide the assessment.

- Survey existing excavated underground structures within Russia and identify feasible sites.
- Develop storage scenarios to be assessed. To accommodate possible delays in disposition, these scenarios should include time periods as long as 100 years.
- Develop design concepts for two selected sites. These should include descriptions of packaging methods, materials protection, control and accounting (MPC&A) systems; monitoring instrumentation; transportation requirements and any needs for infrastructure not present at the selected sites.
- Develop cost estimates and implementation schedules. These should include capital and operating costs and construction schedules.
- Identify safety and environmental risk issues for selected approaches.
- Identify key implementation issues and uncertainties, including public acceptance or conflicting site missions.
- Compare the assessment results and concepts (particularly cost and implementation time) with those of the new Mayak storage facility.

2.2 STORAGE OF SPENT-FUEL, INCLUDING SPENT MOX FUELS

Using plutonium as MOX in existing Russian VVER-1000 reactors will result in spent MOX fuel. Such irradiation of MOX will make less likely the direct reuse, in current stockpile weapons design, of the residual plutonium in spent MOX fuel, thereby contributing to the irreversibility of the arms reductions. It is not clear that the necessary resources will be available to construct reprocessing facilities in Russia before the nearly complete utilization (as MOX) of excess plutonium from dismantled weapons because sufficient excess plutonium, and even highly enriched uranium from dismantled weapons, will be available, without reprocessing, to supply the anticipated number of Russian reactors with either MOX or low-enriched uranium (LEU) fuels for many decades. Because no construction of new reactors in Russia is currently foreseen to generate a need or demand for using recovered plutonium from reprocessing plants, and because excess plutonium and highly enriched uranium from Russia's dismantled weapons can be used instead, storage of spent MOX and spent LEU fuels probably will become the standard fuel-cycle operation in Russia. For many of the same reasons, the current VVER and RBMK spent LEU fuels in Russia will probably require storage indefinitely. Thus, the author proposes considering an assessment of the various kinds of current and projected Russian spent fuels and their safe, secure storage for an indefinite period (i.e., as long as 50 years). The assessments could include the following key elements:

- Survey the various wet and dry storage methods and the expandability of capacities at sites for various reactor types in Russia.

- Document the various wet and dry storage methods in use for VVER and RBMK spent fuels and applicability of these methods to spent MOX fuels.
- Develop a spent-fuel management-system concept for storing, in Russia, the various kinds of spent fuels for as long as 50 years.
- Identify the Russian infrastructures and industries, including new ones, necessary to implement the spent-fuel storage concepts.
- Identify schedules, costs and safety and environmental issues for selected long-term spent-fuel storage management options.

2.3 DEVELOPMENT OF GLASS AND CERAMICS TO IMMOBILIZE EXCESS PLUTONIUM FOR GEOLOGIC DISPOSAL

In addition to assessing disposition of excess plutonium by using it in existing water reactors, the United States is investigating immobilization technologies for processing excess plutonium into glass or ceramic solid forms suitable for geological burial [3, 4]. Thus, collaborative research into glass and ceramic formulations capable of incorporating plutonium, as well as methods to characterize the performance (particularly extrapolated to geologic time periods) of the glass and ceramic formulations, are of interest to U.S. scientists.

3. Results of NATO Workshop Interactions

Participants in NATO workshop discussions observed that collaboratively developing research proposals is very dependent on specific expertise and interest of actual workshop attendees. The two proposal topics described in Sections 2.1 and 2.2 (i.e., interim storage of excess plutonium in existing underground structures and storage of spent fuel) were not developed during the workshop because attendees did not have that specific expertise nor interest. However, several NATO advisory board members attending the workshop, and having a broader vision, suggested that these two topics, because of their appropriateness and timeliness, might be pursued after the workshop. Thus, if specific Russian collaborators can be identified, the author will consider developing proposals for NATO Advanced Research Workshops on the topics.

During workshop discussions, attendees identified two areas (one of which is described in Section 2.3) as being of specific interest to the ongoing excess-plutonium-disposition programs at the United States' Lawrence Livermore National Laboratory. The author plans to collaborate with the two Russian workshop attendees to make specific expert-visit proposals to NATO on those two topics:

- Development and characterization of SYNROC ceramic formulations for excess plutonium, in collaboration with the V. G. Khlopin Radium Institute—St. Petersburg

- Development of pyrochemical methods to remove gallium impurities from excess plutonium during conversion to plutonium oxide and prior to fabrication into MOX fuel, in collaboration with the State Scientific Center: Research of Atomic Reactors—Dimitrovgrad

The author established numerous contacts with Russian scientists and discussed with them a range of topics for possible collaborative proposals, including the following:

- Computerized waste-management-modeling validation exercises based on the Russian radioactive-solution well-injection data at Tomsk-7 and Krasnoyarsk-26

- Impacts of MOX use in Russian VVER-1000 reactors

- Nuclear-ship-decommissioning techniques

- Nuclear-ship spent-fuel storage challenges

- Acceptable radionuclide limits in contaminated scrap recovered from decommissioned Russian nuclear submarines

The outcome of these discussions is presently unknown, but it is certain some will result in further scientific interactions.

4. Acknowledgment

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